Development of Countermeasures to Enhance Sensorimotor Adaptation

Completed Technology Project (2008 - 2012)

Project Introduction

During adaptation to novel gravitational environments, sensorimotor disturbances have the potential to disrupt the ability of astronauts to perform required mission tasks. The overall goal of this project is to gain the information necessary to develop a comprehensive sensorimotor adaptability (SA) training program to facilitate rapid adaptation to novel gravitational environments. It has been previously shown that subjects trained to adapt to varied sensorimotor challenges can adapt faster to new sensory environments that they have never experienced before. This is a process known as adaptive generalization and it allows you to enhance the ability to learn how to learn to adapt to novel environments. By applying these motor-learning concepts for training astronauts we can enhance their ability to rapidly adapt their behavioral responses following a gravitational transition. To minimize cost and demands on crew time we have integrated SA training with existing exercise activities, namely treadmill walking. The SA training program we are developing entails manipulating the sensory conditions of treadmill exercise to systematically challenge multiple sensorimotor systems while conducting nominal exercise activities. To provide SA training we have mounted a treadmill on a six degree-of-freedom motion base to produce variation in the support surface along with variation in visual input during walking using both a projected virtual scene that produces variation in visual flow or through goggles that distort visuomotor information.

Below is an overview of our research results to-date:

Study 1. Aim: Determine whether sensorimotor adaptability (SA) skills learned during treadmill SA training could transfer to a novel discordant sensory environment and to quantify the extent to which any training effects would be retained. This study showed that SA training enhances locomotor adaptability and increases multi-tasking capability during adaption to a novel discordant sensory environment. Results also demonstrated that this increased adaptability can be retained up to 6 months and perhaps longer. Thus SA training improves both locomotor function and multi-tasking capabilities which are essential components required to complete critical mission tasks.

Study 2. Aim: Determine whether performance in a novel discordant sensory environment can be predicted based on a subject's inherent visual dependency. This study showed that subjects with greater visual dependency have decreased locomotor stability and reduced ability to multi-task when negotiating novel sensory discordant conditions. These data indicate that visual dependency may be a marker for decreased ability to adapt to novel environments. Identifying preflight predictors of sensorimotor adaptability can be used to develop individualized training prescriptions that target the specific needs of each crewmember thus making the training process targeted and more efficient.

Study 3. Aim 1: Examine the influence of visual dependence on a subject's SA

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training performance. Aim 2: Determine whether visual dependence influences a person's ability to generalize newly acquired adaptive skills in unfamiliar discordant sensory conditions. This study demonstrated that highly visually dependent individuals receive the greatest benefit from SA training. Although both visually dependent and independent subjects perform equally well by the end of their training, the visually independent subjects outperformed their highly visually dependent counterparts on a locomotor test in a novel sensory discordant environment. This suggests that visually dependent subjects may receive the greatest benefit from SA training but they are less able to generalize their skills.

Study 4. Aim: Determine if SA training using treadmill walking transfers to other functional tasks including manual control. Subjects performed two operationally oriented manual control tests after locomotor SA training. Results indicate that training tasks need to contain at least some of the critical features of the criterion task to be effective. This result informs the design of future training programs ensuring that they contain sufficient locomotor and manual challenges to allow for a comprehensive training across performance modalities.

Study 5. Aim: The goal of this study was to quantify the adaptive locomotor effects, as well as the cognitive and metabolic costs, of exposure to a discordant sensory environment experienced during SA training. Greater metabolic cost incurred during balance instability means more physical work is required during adaptation to new environments possibly affecting crewmembers' ability to perform mission critical tasks during early surface operations on planetary expeditions. Results confirmed that walking in discordant conditions not only compromises locomotor stability and the ability to multi-task, but also increased metabolic cost. Importantly, like locomotor stability and multi-tasking ability, metabolic expenditure while walking in discordant sensory conditions improved during adaptation. This finding confirms that SA training can benefit multiple performance parameters central to the successful completion of critical mission tasks.

Study 6. Aim: The goal of this study was to determine whether performance improvements that result from SA training using visual and support surface discordance would improve performance during exposure to novel vestibular discordance produced by Galvanic Vestibular Stimulation (GVS). GVS has been previously shown to simulate the vestibular disturbances associated with space flight. Results show that SA training enhanced dual-tasking capability during initial exposure to GVS demonstrating that SA training improves performance during simulation of vestibular disturbances associated with exposure to space flight.

Anticipated Benefits

Organizational Responsibility

Responsible Mission Directorate:

Space Operations Mission Directorate (SOMD)

Lead Organization:

National Space Biomedical Research Institute (NSBRI)

Responsible Program:

Human Spaceflight Capabilities

Project Management

Program Director:

David K Baumann

Principal Investigator:

Jacob J Bloomberg

Co-Investigators:

Regina R Buccello-stout
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Millard F Reschke
Helen Cohen
Brian T Peters

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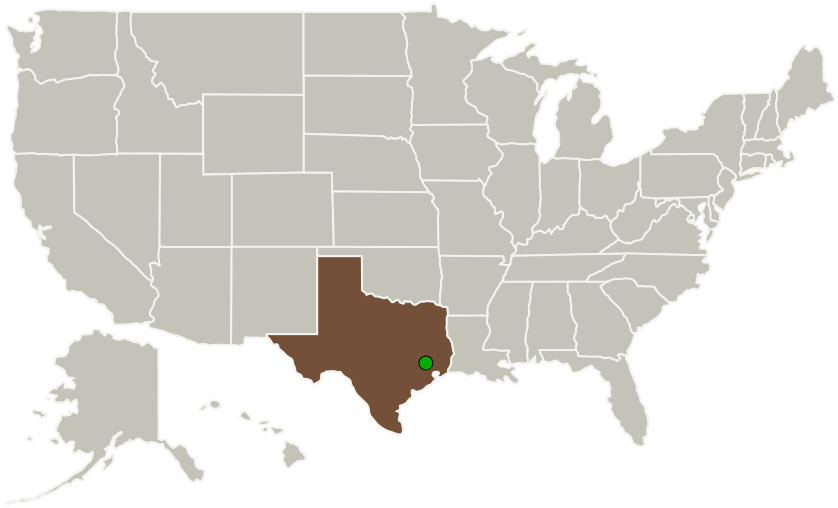
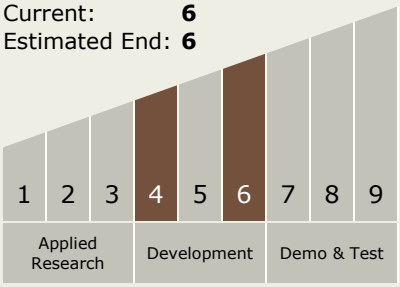
Sensorimotor adaptability training programs have Earthbound application in rehabilitation of patients with balance disorders, and for fall prevention training among seniors. The most important factors underlying morbidity in the older adult population are injurious falls and the restriction of activity due to falls. Approximately 25-35% of community-dwelling persons older than 65 years fall at least once a year, and approximately 40-50% of fallers experience two or more falls. The outcome is that 40% of all nursing home admissions are due to injuries due to falls. Age-related sensory changes and deterioration in ability to compensate in older adults can contribute to increase incidence of falling. We previously conducted a study to determine if balance training using variation in visual flow during treadmill exercise improves functional mobility in healthy older adults who were experiencing age-related postural instabilities (Buccello-Stout et al. 2008). The results showed that subjects who were exposed to varied visual flow during treadmill walking significantly improved their ability to negotiate an obstacle course after training compared to another elder group who only walked on a treadmill for the same amount of time. Importantly, the training benefit was retained when subjects were tested four weeks later. The training also allowed the elder subjects to adopt a head stabilization strategy optimized to maintain postural equilibrium control (Buccello-Stout et al., 2012). These studies confirm that adaptability training developed for use by astronauts can also be used to improve balance and gait performance in elder subjects and points to the general applicability of this type of training in different clinical populations.

Primary U.S. Work Locations and Key Partners



Technology Maturity (TRL)

Start: **4**
Current: **6**
Estimated End: **6**



Technology Areas

Primary:

- TX06 Human Health, Life Support, and Habitation Systems
  - TX06.3 Human Health and Performance
    - TX06.3.2 Prevention and Countermeasures

Target Destinations

The Moon, Mars

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Organizations Performing Work	Role	Type	Location
National Space Biomedical Research Institute(NSBRI)	Lead Organization	Industry	Houston, Texas
Baylor College of Medicine	Supporting Organization	Academia	Houston, Texas
Johnson Space Center(JSC)	Supporting Organization	NASA Center	Houston, Texas
Universities Space Research Association(USRA)	Supporting Organization	R&D Center	Huntsville, Alabama
Wyle Integrated Science and Engineering Group	Supporting Organization	Industry	
Wyle Laboratories, Inc.	Supporting Organization	Industry	

Primary U.S. Work Locations
Texas

Project Transitions

October 2008: Project Start

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September 2012: Closed out

Closeout Summary: 1) In FY12 we completed the data collection and analysis for fifth and sixth studies in this project. 2) During this review period four presentations related to this project were completed at four international scientific meetings. These include: Bloomberg JJ, Peters BT, Mulavara AP, Brady RA, Batson CD, Miller CA, Cohen HS. Countermeasures to enha nce sensorimotor adaptability. Major Problems of Space Life Sciences Conference, Moscow, Russia, October 20-21, 2011. Bl oomberg JJ, Peters BT, Mulvara AP, Brady RA, Batson CD, Miller CA, Ploutz-Snyder RJ, Guined JR, Buxton RE, Cohen HS. Lo comotion adaptation improves balance control, multitasking ability and reduces the metabolic cost of postural instability. N ASA Human Research Program Investigators' Workshop, February 14–16, 2012, Houston, TX. Mulavara AP, Wood SJ, Cohe n HS, Bloomberg JJ. Locomotor dysfunction after long-duration space flight and development of countermeasures to facilitat e faster recovery. 39th Scientific Committee on Space Research (COSPAR), Mysore, India, July 14-22, 2012. Bloomberg JJ, Mulavara AP, Peters BT, Wood SJ, Reschke MF. Sensorimotor countermeasures: Improving performance during gravitationa l transitions. 84rd Annual Scientific Meeting of the Aerospace Medical Association, Chicago Ill, May 12-16, 2013. 3) Seven manuscripts were published or are in press: Batson CD, Brady RA, Peters BT, Ploutz-Snyder RJ, Mulavara AP, Bloomberg JJ. Gait training improves performance in healthy adults exposed to novel sensory discordant conditions. Experimental Brain R esearch. 209(4): 515-24. 2011. Brady RA, Peters BT, Batson CD, Ploutz-Snyder RJ, Mulavara AP, Bloomberg JJ. Gait adapt ability training is affected by visual dependency. Experimental Brain Research. 220: 1-9. 2012. Buccello-Stout RR, Cromwel l RL, Bloomberg JJ, Whorton EB. Effects of sensorimotor adaptation training on head stability movement control in response to a lateral perturbation in older adults. The Journal of Aging and Physical Activity. In Press. Brady RA, Brian BT, Bloomberg JJ. Walking on an oscillating treadmill: Strategies of stride-time adaptation. Ecological Psychology. 24: 265-278. 2012. Mula vara AP, Ruttley T, Cohen HS, Peters BT, Miller C, Brady R, Merkle L, Bloomberg JJ. Vestibular-somatosensory convergence in head movement control during locomotion after long-duration space flight. Journal of Vestibular Research. 22(2):153-66. 2012. Cohen HS, Kimball KT, Wood SJ, Paloski WP, Bloomberg JJ, Mulavara AP. The role of posturography and locomotor te sting in assessing performance in astronauts. Journal of Vestibular Research. 22(4): 191-6. 2012. Peters BT, Brady RA, Bat son CD, Guined JR, Ploutz-Snyder RJ, Mulavara AP, Bloomberg JJ. Changes in locomotor stability, cognition, and metabolis m during adaptation to walking in discordant sensory conditions. Aviation, Space, and Environmental Medicine, In Press.

Stories

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Project Website:

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